

PNEUMOCONIOSIS IN CHILEAN MINERS OF THE 16TH CENTURY

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THE entire orientation of the Spanish colonial system in the Americas was toward the finding of precious metals and gems. After the plundering of all mined metal it became necessary to turn to mining to satisfy the demands of the crown. Such mines began at an exposed mineral vein and followed its course, becoming wide or narrow and branching as the vein branched. Shoring was at a minimum, in the form of a few bracing trunks or rough stone walls. As the mine deepened the miners were obliged to climb woven cowhide ladders with 50 lb. sacks of ore on their backs, saving light by having a candle tied to the thumb of each third man. Climbs of 500 to 1,000 feet under such conditions were not unusual. Accidents were frequent.

Explosives were not used to free the ore; instead, the mineral was pried out by means of heavy iron bars. Even under these circumstances the air was thick with dust and metallic vapors. Most mines were closed prematurely when the air became incapable of supporting human life, since air-shafts were not used. Under such conditions the working life of a miner was from six to 18 months; by the 17th century mining production declined because workers were no longer available. Mining killed more Indians in greater Peru than all the epidemics in the Americas combined. In 1629 for example, 80,000 Indians were mustered for the mines but in 1678, a scant 45 years later, only 1,674 could be found.¹⁻³

Although it is not known why the miners died so soon after enter-

ing the mines, much speculation has been offered. Juan Lastre, in his *History of Peruvian Medicine*,⁴ stated that the symptoms described in the Spanish chronicles were those of pneumoconiosis; he called this the first industrial disease in the Americas. Since it is the oldest and best known of all occupational diseases of the lungs, having been described by Hippocrates in 460 B.C., it was a shrewd choice. The present report is a preliminary study of the pathological findings in the lungs of 22 individuals, 12 of whom were obviously associated with the mining or processing of ore. These Indians lived in greater Peru, which had been part of the Inca empire before the Spanish conquest.

MATERIALS AND METHODS

We studied the lungs of 22 mummies from a group of 100 excavated during the last 10 years from a cemetery near Pica, Tarapaca, in Northern Chile. This area is at an altitude of about 2,000 meters. The 22 randomly chosen mummies were carefully autopsied and their organ systems dissected. Gross and microscopic examinations were conducted in the Department of Pathology of the Medical College of Virginia.

The lungs were studied in the dried condition and photographed. Representative sections then were rehydrated in Ruffer's solution and standard paraffin sections were made. All tissues were studied unstained with normal and polarized light and after staining with NAFT stain,* Ziehl-Neelsen (carbofuchsin), Alcian blue, periodic acid-Schiff (PAS), Gomori silver methenamine, Masson's trichrome, and McKee's modification of Gram's stain.

RESULTS

Three carbon-14 tests placed these mummies at about 1550 to 1600 A.D. Preliminary analysis showing the presence of mercury placed them later than 1571 A.D.

Since mining in Spanish colonial America involved men, women, and children, the lungs of the adults were separated from those of the children. The findings in these lungs are shown in the accompanying table.

Three of the 22 sets of lungs were from children estimated to be less than three years of age. Gross examination revealed lungs of nor-

*A quick hematoxylin and eosin type stain used for frozen sections (Allied Chemical).



Fig. 1. Gross specimen of the right lung with the pleura removed. Note the extensive emphysema in this adult.

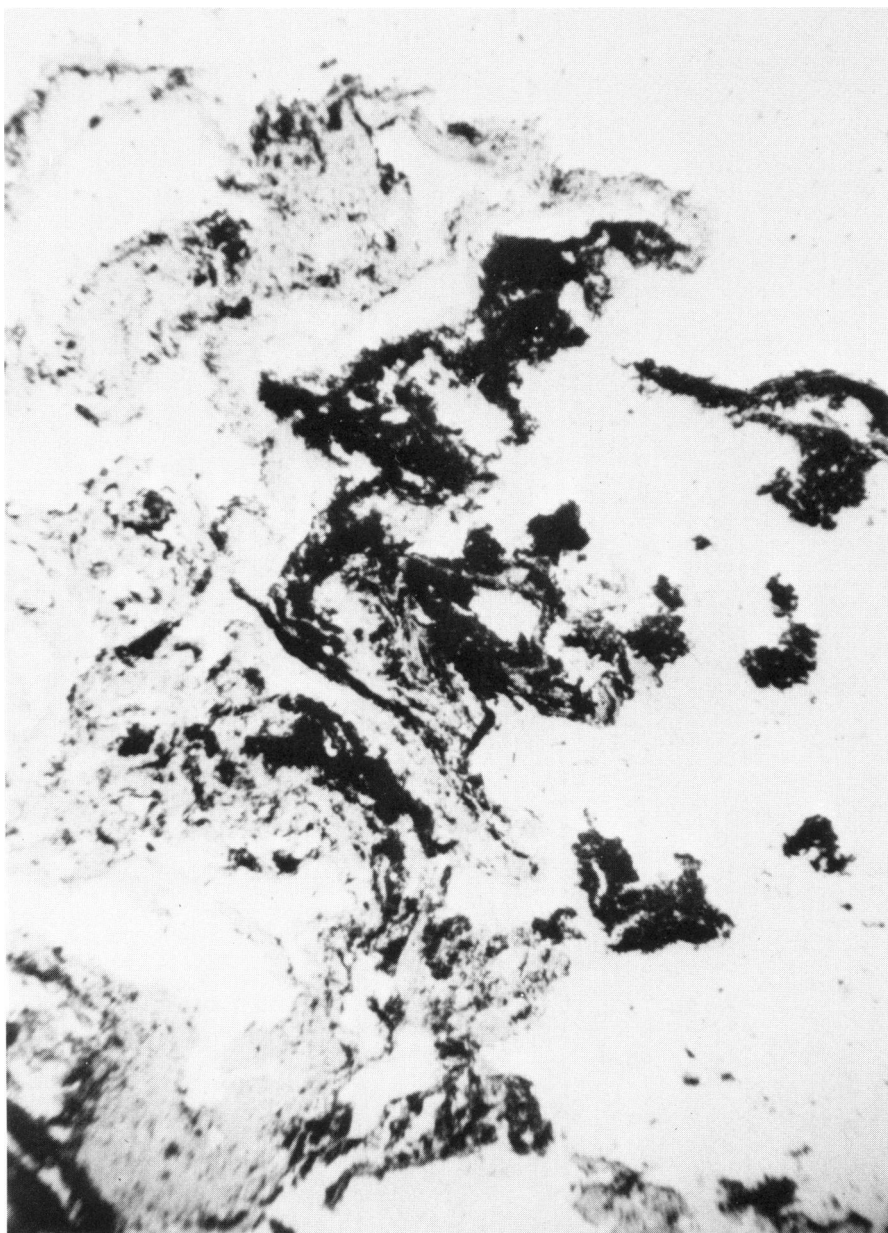


Fig. 2. Unstained section showing the heavy deposits of ore in the lungs of this adult.
40X.

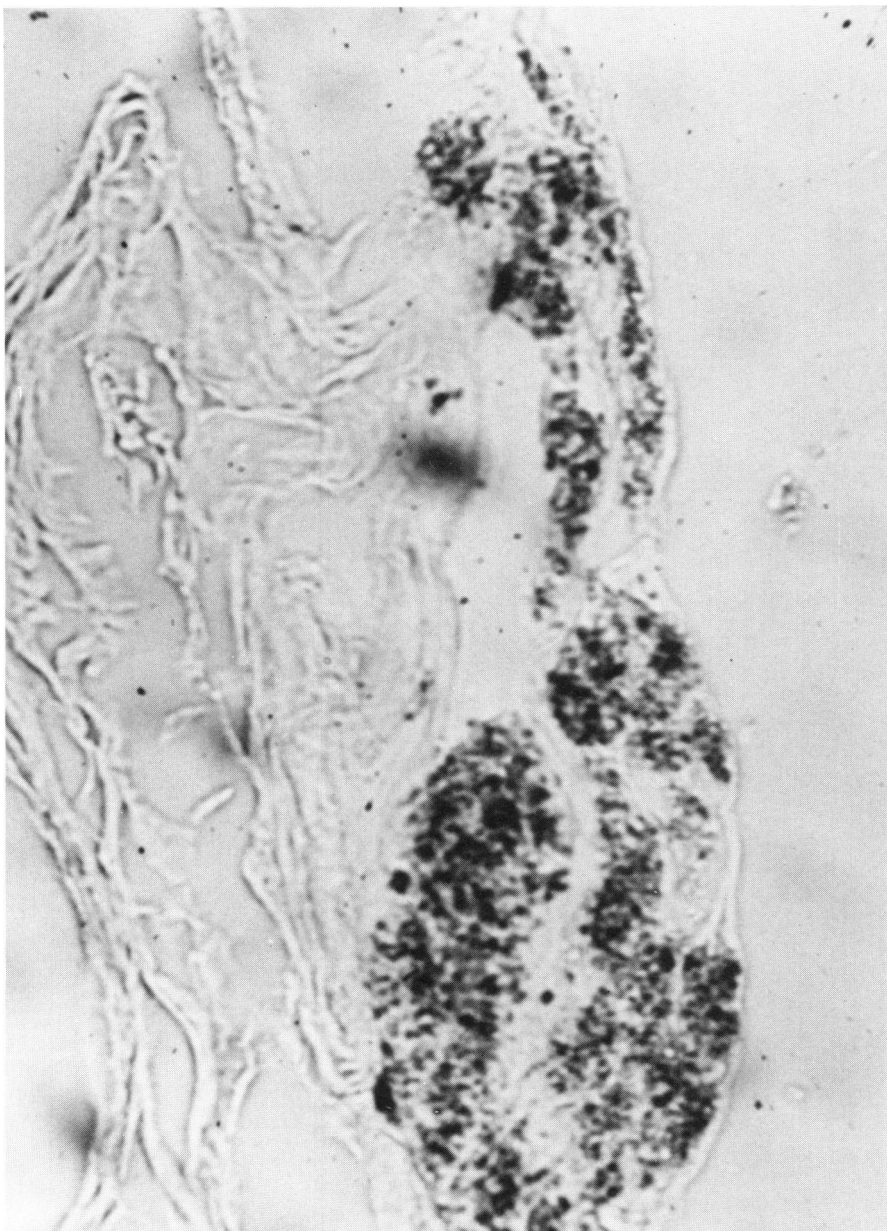


Fig. 3. Unstained section of lung seen on high-dry magnification ($440\times$) to show the size of the dust particles.

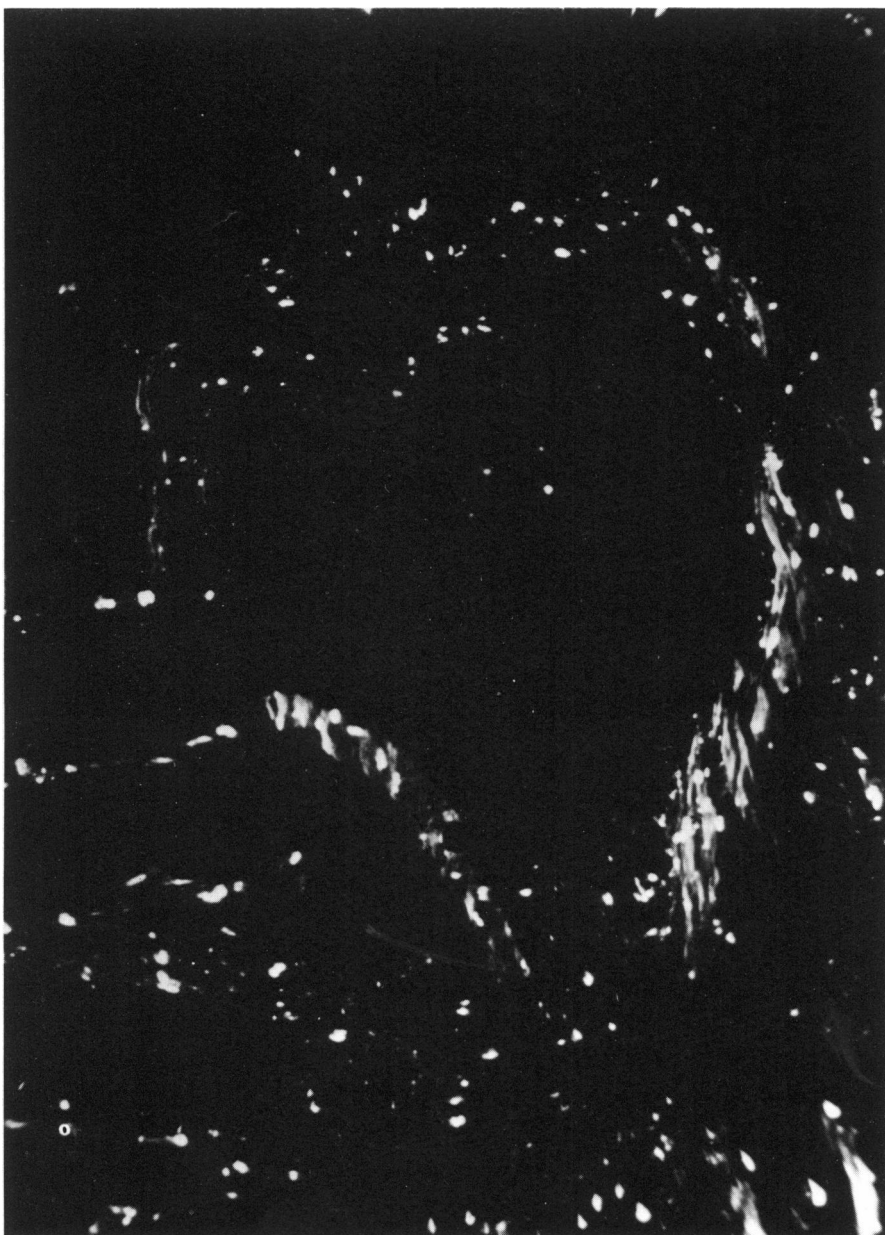


Fig. 4. Unstained section of lung seen on high-dry magnification under polarized light. The granules of light are silica and the fibrils are fibrous tissue. 440 \times .

DISTRIBUTION OF PULMONARY DISEASE

No.	<i>Pneumoconiosis</i>	<i>Silica</i>	<i>Pneumonia</i>	<i>Normal</i>
Children* 3	0	0	2	1
Adults 19	12	12†	10‡	6

* Estimated as less than three years of age.

† Two of those with silica had extensive granulomas with what appeared to be caseation.

‡ One showed pneumonia but no pneumoconiosis.

mal color in all three, but two specimens showed gross evidence of pneumonia, edema fluid being present at the time of death. One was normal in every way.

The remaining 19 sets of lungs belonged to adults; 12 of these were grossly black but the bases were of normal color. Removal of the pleura revealed extensive evidence of emphysema (Figure 1) in these 12; in some cases cavities had formed. Microscopic examination of unstained sections showed severe pneumoconiosis in these 12 (Figure 2). The dust consisted of two types: 1) a black material (Figure 3) that on preliminary analysis was shown to contain silver, copper, and iron and 2) birefringent particles of silica (Figure 4). In three lungs bluish-green crystals of copper salts were also seen (Figure 5). The silica was in close proximity to the other dust and was considered to be evidence of hard-rock mining, the black material being ore. Seven of the adult lungs were completely normal in color and of these six were normal in consistency. One showed evidence of pneumonia. Nine of the lungs with pneumoconiosis also had the characteristics of pneumonia and two of these had lesions resembling granulomas with caseation. A tracheobronchial lymph node from one such individual is shown in Figure 6. Gram's stain was done but the results were not rewarding, as no predominant organism was outlined by it. Extensive search of multiple sections stained with Ziehl-Neelsen stain failed to reveal acid-fast bacilli in the lungs or tracheobronchial lymph nodes. Masson's trichrome stains revealed extensive diffuse fibrosis in the 12 lungs showing pneumoconiosis. Five of the nine lungs from this group, also diagnosed as having pneumonia, had large amounts of PAS-positive granular material in the alveolar spaces and were negative to Alcian blue stain, sug-

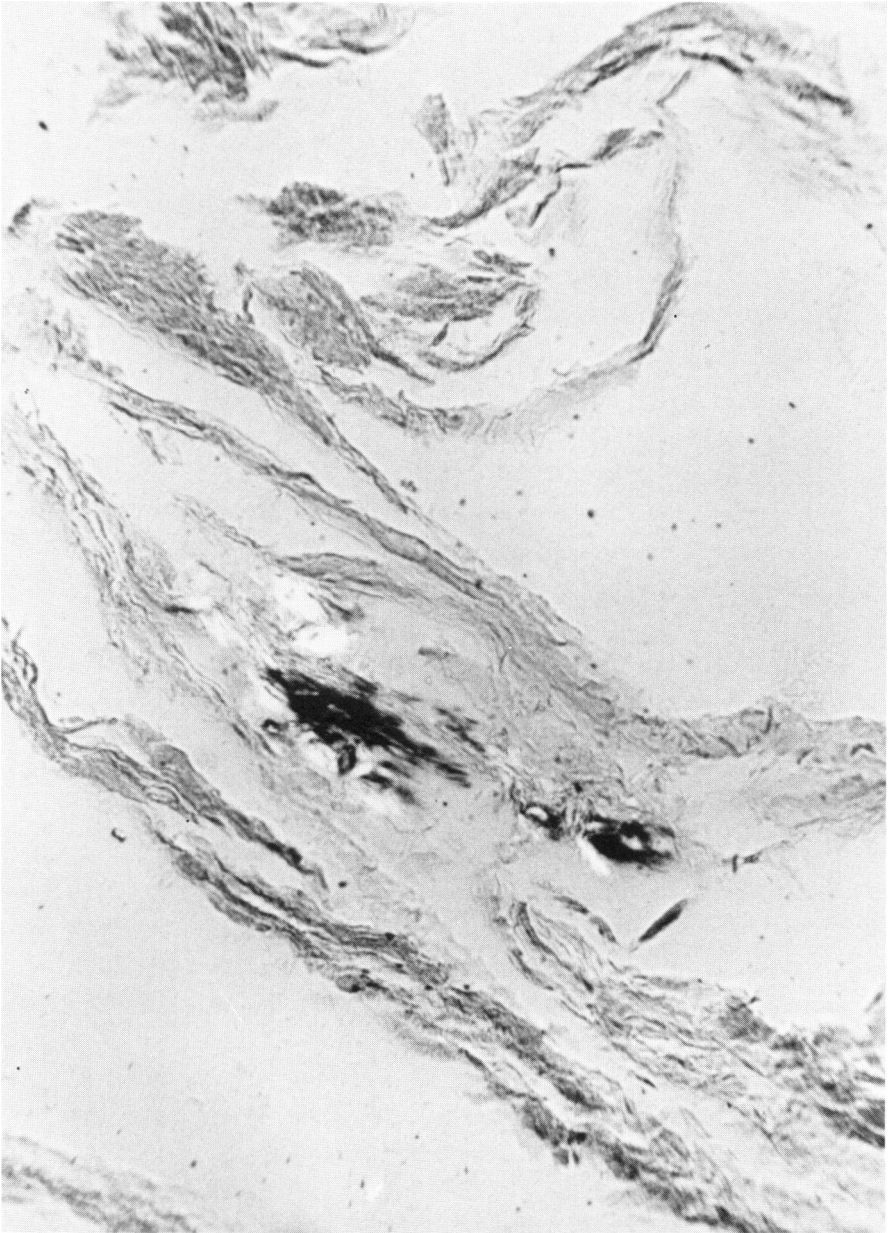


Fig. 5. Unstained section of lung showing copper salt crystals (black) associated with silica (bright areas). 440 \times .



Fig. 6. Caseous tracheobronchial lymph node with diffuse calcium deposition in central area. Multiple sections of this and similar pulmonary lesions stained by the Ziehl-Neelsen technique were negative for acid-fast bacilli. 40 \times .

gesting the possible diagnosis of alveolar lipoproteinosis (Figures 7*a* and 7*b*).

DISCUSSION

The opportunity to study the bodies of 22 members of a mining community that existed nearly 500 years ago has given scientific confirmation to the statements made by Spanish chroniclers as to conditions of work in the mines. Twelve individuals had obviously worked in the pits, since their lungs showed extensive pneumoconiosis and silicosis. The type of disease is a diffuse pneumoconiosis with interstitial fibrosis complicated by pneumonia in nine cases, with what appears to be alveolar lipoproteinosis in five of these miners. Two individuals had cavitary and granulomatous lesions suggestive of mycobacterial disease but no organisms were seen.

The acute form of silicosis was first described in 1929 by Middleton,⁵ the differentiation being based in part on the history of short exposure to silica dust followed by rapidly developing constitutional symptoms. In the present study it was impossible to state the duration of exposure, but the quantity of silica present indicates a massive exposure, and this agrees with the statements of Father Acosta.⁶ MacDonald et al.,⁷ in presenting their two cases of acute silicosis, mention the presence of an "albuminous exudate," but they did not utilize PAS stains. Their patients died within two months of the onset of illness. Buechner and Ansari's⁸ report of four cases is the first good description of the relation between exposure to silica and a pulmonary reaction which resembles alveolar proteinosis. They suggested the name silico-proteinosis.

The development of protective devices and laws supposedly has reduced this severe form of silicosis in the last 25 years, but a recent study by Bailey et al.⁹ on 83 sandblasters in New Orleans yielded some astonishingly similar findings. Twenty-two of the patients had mycobacterial infections and eight of those with positive cultures died. Three of these eight had a disease resembling pulmonary alveolar proteinosis. One had acute silicosis with thickening of the alveolar wall while two had massive fibrous consolidation.

Preliminary chemical studies on the lungs of our mummies revealed extremely high levels of mercury and lead in the lungs of one individual. This is probably related to smelting and is under further investi-

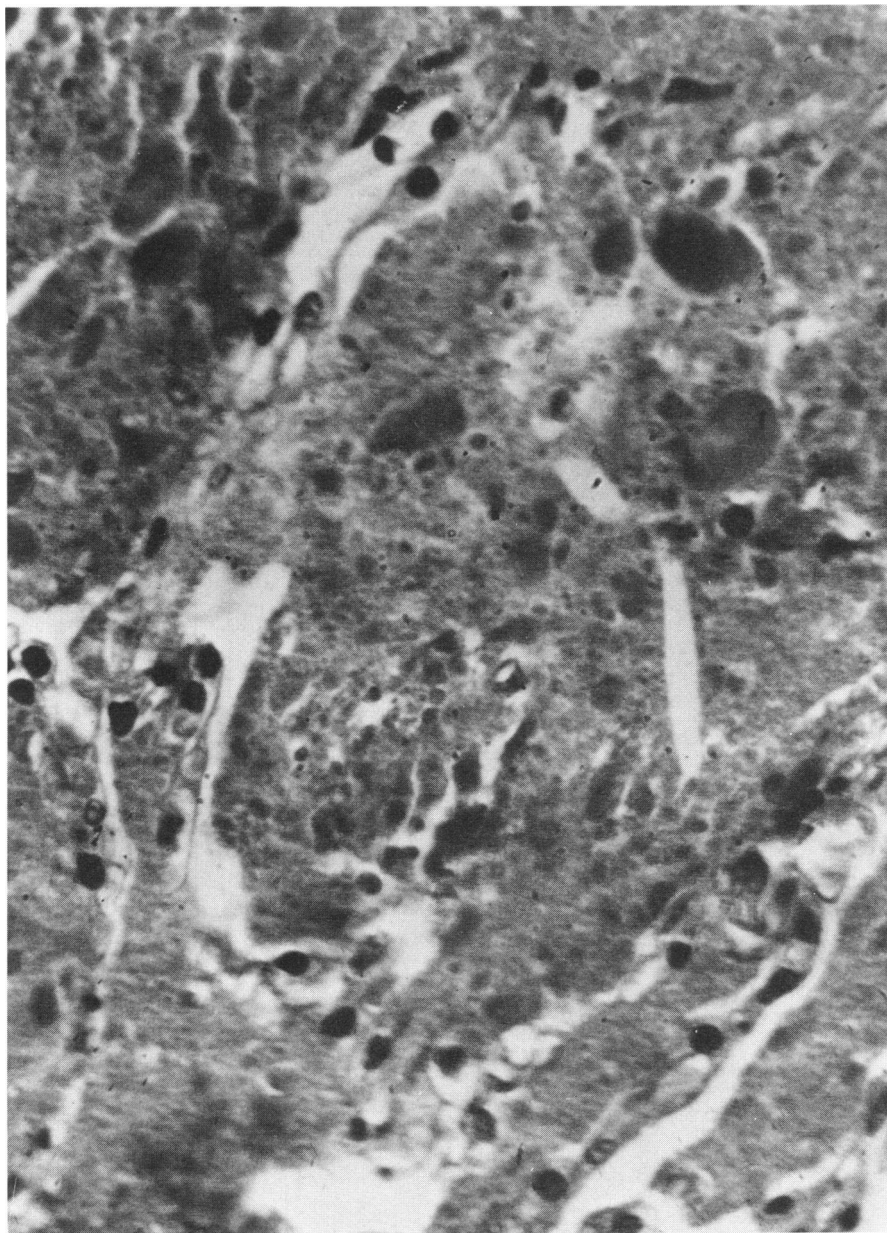


Fig. 7a. Alveolar proteinosis from a modern lung with areas of PAS-positive material.
440X.

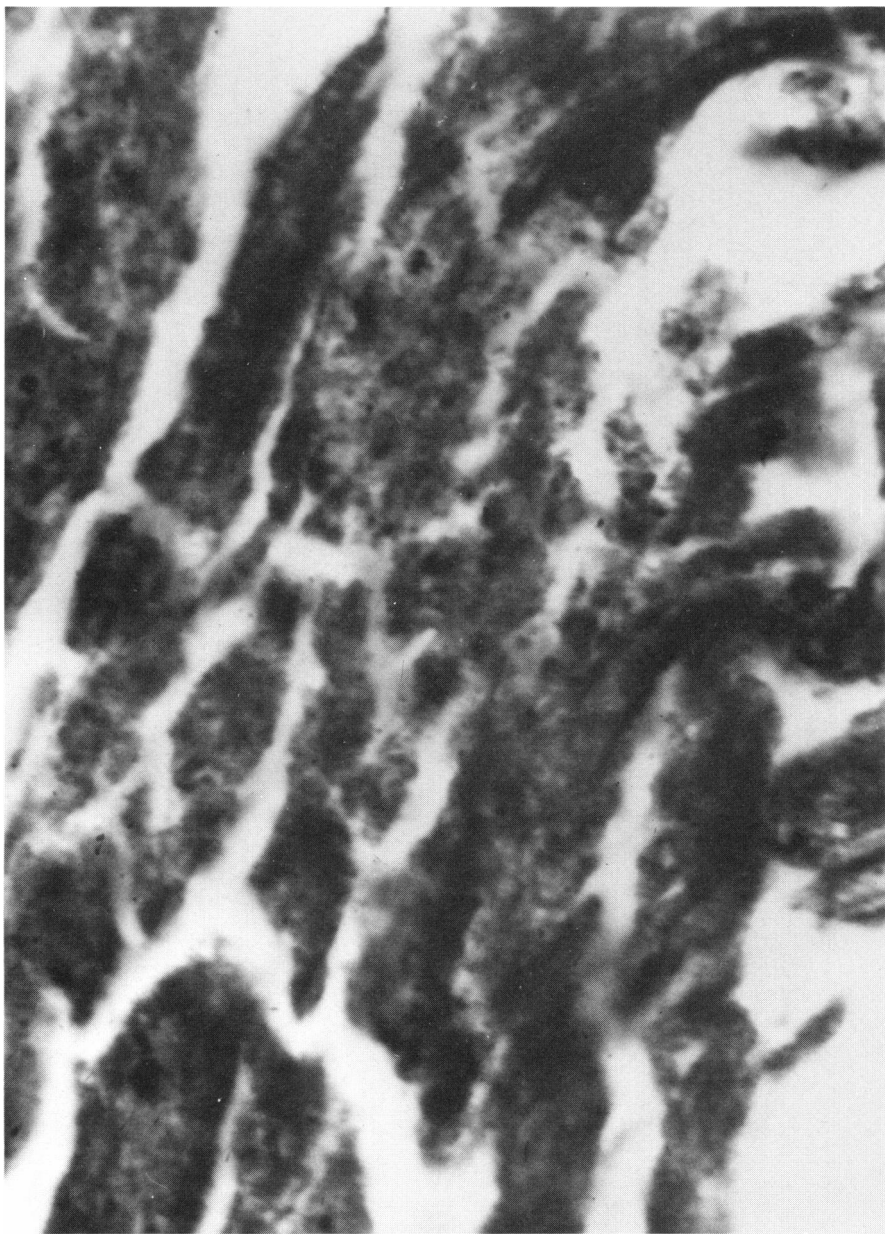


Fig. 7b. Alveolar proteinosis from the lung of a Tarapacan miner showing areas of PAS-positive material similar to those in Figure 7a.

gation. The presence of mercury is an aid in dating, since mercury was not used in American mining prior to 1571. The mines of Huancavilica in present-day Peru were discovered by Enrique Garces, a Portuguese, in 1566-1567 and were the only source of mercury in the Americas for many years.

This preliminary report confirms the presence of severe occupational pulmonary disease. Further studies now in progress will determine the frequency of heavy-metal poisoning and studies of bones will determine the accident rate.

SUMMARY

We have studied mummies of miners from approximately 1600 A.D. for evidence of occupational disease. Twelve cases of pneumoconiosis and acute silicosis due to hard-rock mining are described. The conditions of the lungs were compatible with descriptions of occupational conditions encountered in Spanish writings of the period.

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